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Research paper

GIS Analysis & Landslide Susceptibility Mapping (LSM) in Murum Reservoir Region, Sarawak.

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Abstract

Landslides in Malaysia are mostly triggered by rainfall throughout the years. Therefore, it is important to carry out Landslide Susceptibility mapping (LSM) on high prone areas to minimize the destruction caused by unexpected landslides events. Landslides around Murum Reservoir might trigger debris flow into the reservoir which will cause overtopping of Murum Dam. This study looked into the relationship of possible landsliding variables such as slope, elevation, aspect, curvature, basic geology and soil around Murum Dam Reservoir. For LSM, different thematic maps such as slope map, elevation map, curvature map, geology map and drainage buffer map are integrated in GIS according to weighted analysis method perform by several authors in previous literature studies. The LSM shows that there are few high susceptible areas and will be coupled with Transient Rainfall Infiltration and Grid-Based Regional Slope Stability Analysis (TRIGRS) in future to predict changes in factor of safety and pore water pressure of susceptible areas over a period of storm events.

Keywords: *Landslide Susceptibility Mapping; Rainfall; Murum Reservoir; GIS; weighted analysis; Landslide hazard map*

1. Introduction

Landslide is the product of a widespread of processes which include geomorphology, geological and meteorological factors [1]. Although gravity acts as main driving factor for landslides occurrence, there are other factors which contribute to the occurrence of landslide. The important factors contribute to landslides are discussed by [2] and [3]. The most important factors are bedrock geology (lithology, degree of weathering), geomorphology (slope elevation, aspect, relative relief), soil (depth, permeability, porosity), land use land cover and hydrology conditions (pore water pressure) [1].

Majority of landslides in Malaysia took place on embankments or cut slopes alongside highways and roads located in mountainous areas [4]. Thus, it is obligated to identify potential landslides areas to minimize the destruction. As Malaysia is a tropical country, abundance of rainfall is considered as triggering factor for landslides case studies. Studies carried out by [4, 5, 6] showed rainfall has dependency relationship with the occurrence of landslide. GIS is the preferred way in conducting landslide hazard assessment. Several authors such as [1, 7, 8] had conducted research on GIS based landslide hazard zonation.

1.1 Problem Statement

Landslide is known as one of the costliest geo-hazards around the world as it causes fatalities and contributes to major economic losses. In Malaysia, statistics had reported landslides and fatalities from 1973 to 2007, indicating an increase number of fatalities with an incline number of landslides [9]. Thus, it is vital to recognize the potential prone areas to minimize fatalities. Rainfall is considered the main factor for landslides in Malaysia. Data provided by Sarawak Management Master Plan shows that the annual precipitation in Sarawak is approximately 4000 mm. Blessed with abundance of water throughout the year, hydroelectric power generation is highly potential and suitable in Sarawak.

The rise in hydroelectric power plants will create more man made reservoirs. Landslides around Murum reservoir area could trigger debris flow slides and cause a tsunami overtopping the dam. The overtopping scenario could inundate the downstream of Murum Reservoir. So, landslide prediction map should be done to predict those unstable areas before any landslide happen.

As Murum Reservoir is located in hilly and mountaineous area, geospatial technique using GIS to map the area is recommended. Geospatial technique is famous among researchers due to its capability of reaching every part of the area, identifying location of prone areas based on causative factors such as terrain type, geology, slope and soil [1].

1.2 Study Area

The study area is located in Murum Reservoir at Belaga District, Kapit Division of Sarawak. It is within the coordinates of 114°21.4’ E to 114°22.4’ E and 2°38.5’ N to 2°39.4’ N. The reservoir has a surface area of 245km2. A Roller Compacted Concrete (RCC) Dam is seated at the downstream of Murum Reservoir, with a volume of 12.4x109m3 at the uppermost part of Rajang River Basin as shown in Figure 1.

Figure 1 Location of Murum Reservoir

2. Method of Research

2.1 Preparation of Data Layers

ASTER DEM data is downloaded from the NASA website. Digital Elevation Model (DEM) is used to create topographic maps, such are slope, aspect, elevation, curvature, contour and relative relief. Detailed drainage analysis is performed using DEM fill, sink removal on the basis of reservoir lake shapefile. Regional geology map and soil classification map are digitized and georeferenced in GIS environment. Recent rainfall data from Murum Spillway is tabulated and analyzed as an input for LHZ map. Weighted analysis is performed to generate Landslide Hazard Zonation for Murum Reservoir. Figure 2 shows the flowchart of data layers.

3. Results and Discussion

3.1 Geology

Geological sediments around Murum reservoir area is divided into five parts. Murum reservoir area mainly consists of the Palaeogene Sedimentary rocks (eg. Argillaceous rocks, some arenacrous and calcareous beds). At the southwest of Murum Dam, there is a presence of Pliestocene and Recent sedimentary rocks (eg. Clay, silt and peat). At the upstream of Murum Reservoir, there are 3 major groups, which consist of Cretaceous-Quaternary Igneous rocks (eg. Dacilitic and andesitic lava and pyroclastics), Neogene Sedimentary rocks (eg. Arenaceous and argillaceous rocks, coal and calcerous beds) and also the Triassic-Quaternary Igneous rocks (eg. Andelistic and basalitic lava and pyroclastics). The regional geology of Murum Reservoir area is indicated in Figure 3, an extract from the 1:500 000 Geological Map of Sarawak, by Geological Survey of Malaysia, 1992.

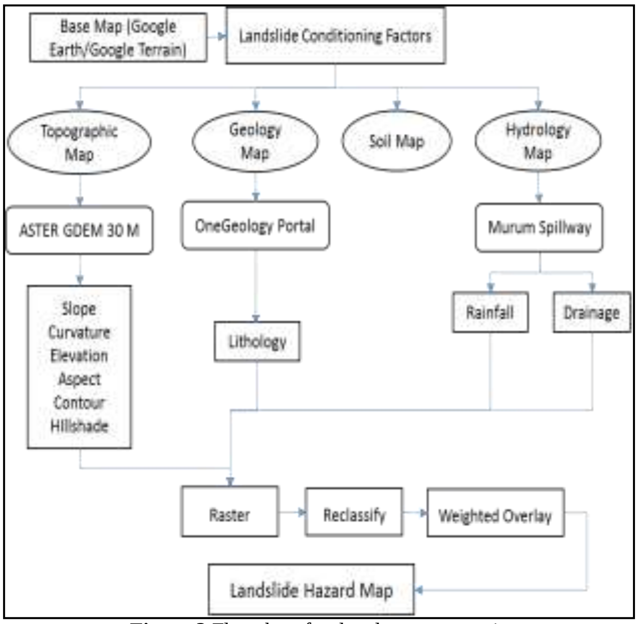

Figure 2 Flowchart for data layer preparation

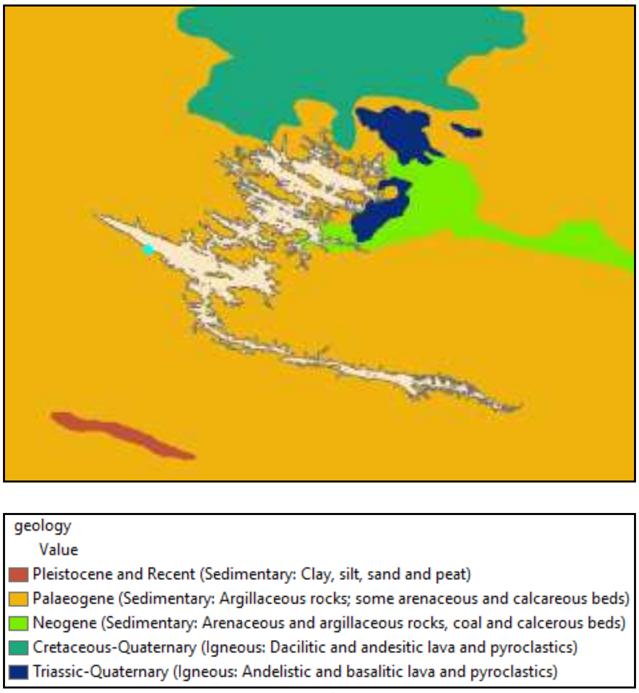

Figure 3 Geology of Murum Reservoir

3.2 DEM derivatives

Slope, aspect, curvature and elevation are of great importance in landslide studies. Slope in the present area varies from 0° to 64.2° with abrupt relief prevails over the area. Curvature ranges from -7.25 to 6.86. A positive curvature indicates the surface is upwardly convex at that cell. A negative curvature indicates the surface is upwardly concave at that cell. A value of 0 indicates the surface is flat. Meanwhile, aspect is found to be mainly on north, south and south west face, which can have huge impact on mass movement events because rainfall events tend to be more in these faces. Elevation which ranges from 39m to 1912m. Relative relief ranges from 417m to 1076m.

3.3 Drainage Analysis

Drainage map is created from ASTER DEM using ArcHydro extension tool. Almost all the drainages are well connected to the reservoir. Due to highly undulating nature of the area, large number of small drainage, which are basically active in rainy season are found. This drainage network got a compelling relation with the occurrence of landslides. To conduct proper assessment of landslides, drainage, road and reservoir buffer maps of 50m, 100m, 200m, 500m, 1000m respectively are prepared.

3.4 Soil Classification

Soils in Murum Reservoir area are mainly skeletal soils (SS) and red-yellow podzolic soils (RYPS). These are very shallow to moderately deep loamy sands to clays and occur mainly on steep and mountainous land.

At the downstream of the Murum Reservoir, there are mixture of gley soils (GS) and RYPS. GS are poorly drained sands to clays and exist on recent alluvium in floodplain areas or on an old alluvium on low level terraces and also exist on sedimentary rocks on gently undulating land and some dip slopes. RYPS are shallow to deep, yellow to red loamy sands to clays, mostly found on sedimentary, acid igneous and metamorphic rock, and exist on gently sloping to steep land.

The soils at the upstream of Murum Reservoir, consists of traces of RYPS and a mixture of GS and RYPS. Thus, soil quality varies with the elevation and annual rainfall. Elevation ranges roughly from 30m to 1900m in Murum Reservoir area. Rainfall varies according to the aspect of slope faces. Each category of soil has corresponding influence and contribution to the occurrence of landslides.

Soil classification map of Murum Reservoir area, as part of extracted version from Soil Map of Sarawak 1982, by the Department of Agriculture of Sarawak.

3.5 Landslide Susceptibility Mapping

Weighted rating system is based on the relative importance of various causative factors derived from field knowledge [7].

Input data layers such as aspect map, slope map, soil map, geology map are assigned an influence value (total 100%) according to their corresponding impact on the landslide occurrence.

Figure 4 shows different classes of input layers are assigned a rating scale of 1 to 5 where 5 represents class with the highest impact on landslide. Table I summarizes the influence and ratings. After reclassify and overlay, a landslide susceptibility map is prepared as shown in Figure 5.

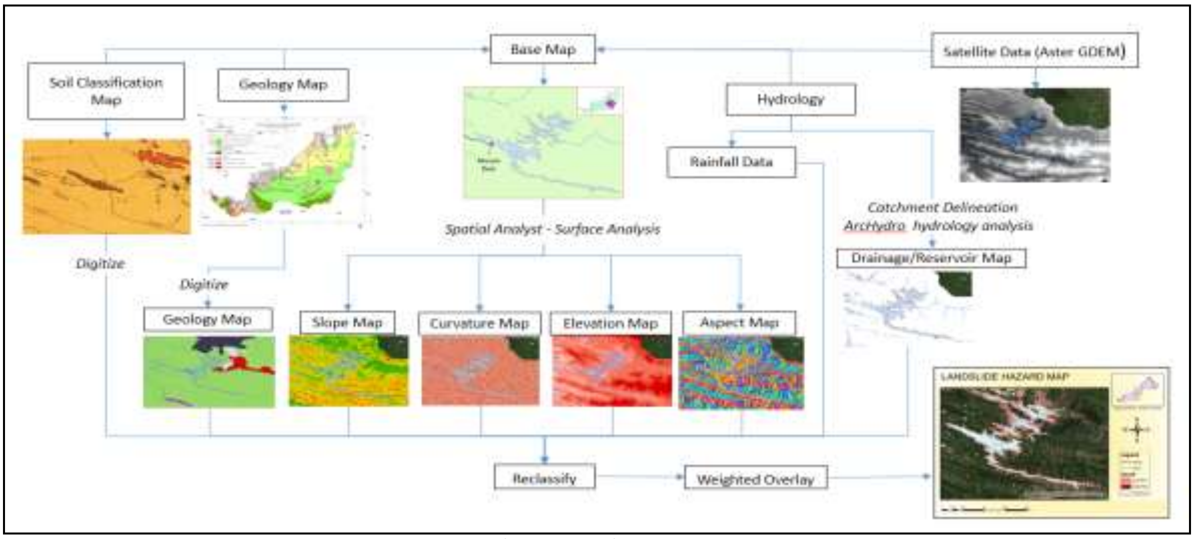

Figure 4 Preparation of data layers for Landslide Susceptibility Map

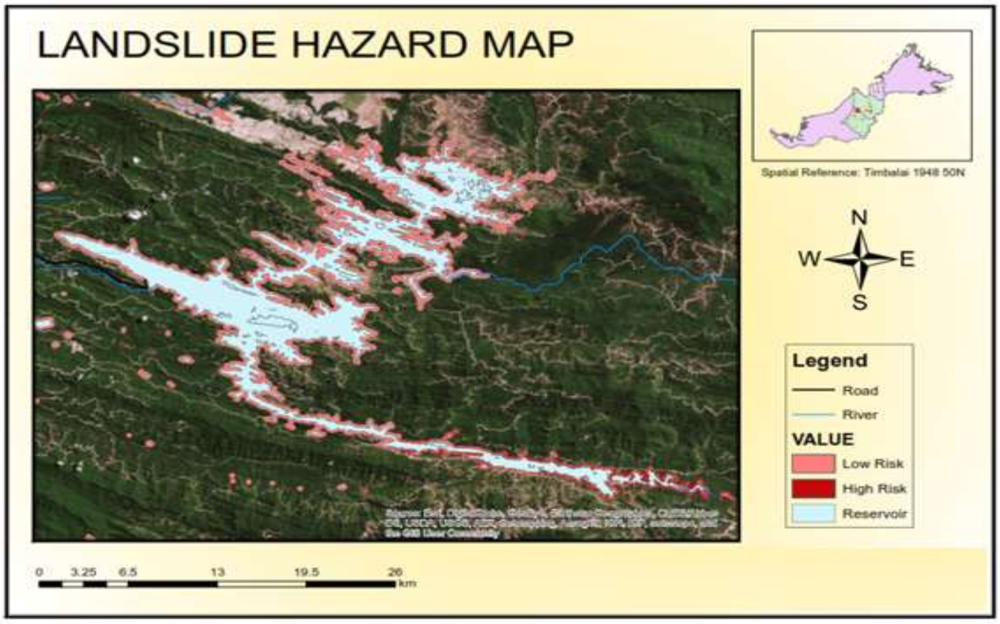

Figure 5 Landslide Susceptibility Map

Table 1 Summary of weighted analysis [1, 5, 6]

No	Landslide Factors	Influence (%)	Reclassify Class Code									
			1	2	3	4	5	6	7	8	9	10
1	Slope gradient (°)	10	0-7.049827785	7.049827786 - 13.34431688	13.34431689 - 19.38702641	19.38702642 - 26.43685419	26.4368542 - 64.20378876	/	/	/	/	/
2	Aspect (°)	10	Flat (-1)	North (0-22.5)	Northeast (22.5-67.5)	East (67.5-112.5)	Southeast (112.5-157.5)	South (157.5-202.5)	Southwest (202.5-247.5)	West (247.5-292.5)	Northwest (292.5-337.5)	North (337.5-360)
3	Elevation (m)	10	39 - 353	353.0000001 - 590	590.0000001 - 827	827.0000001 - 1,104	1,104.000001 - 1,912	/	/	/	/	/
4	Hillshade	10	0 - 114	114.0000001 - 147	147.0000001 - 175	175.0000001 - 203	203.0000001 - 254	/	/	/	/	/
5	Relative relief	10	417.8754272 - 612.5465698	612.5465699 - 746.6954346	746.6954347 - 843.9668579	843.966858 - 936.4830933	936.4830934 - 1,075.953979	/	/	/	/	/
6	Curvature	5	-7.257714272 - -0.558553621	-0.558553621 - 0.170998873	-0.170998873 - 0.161190912	0.161190912 - 0.604110624	0.604110624 - 6.860351563	/	/	/	/	/
7	Drainage buffer (m)	10	50	100	200	500	1000	/	/	/	/	/
8	Reservoir buffer (m)	15	50	100	200	500	1000	/	/	/	/	/
9	Road buffer (m)	5	50	100	200	500	1000	/	/	/	/	/
10	Geology	15	Pleistocence and Recent (Sedimentary rocks: Clay, silt, sand and peat)	Palaeogene (Sedimentary rocks: Argillaceous rocks, some arenaceous and calcareous beds)	Neogene (Sedimentary rocks: Arenaceous and argillaceous rocks, coal and calcerous beds)	Cretaceous-Quaternary (Igneous rocks: Dacilitic and andesitic lava and pyroclastics)	Triassic-Quaternary (Igneous rocks: Andelistic and basalitic lava and pyroclastics)	/	/	/	/	/

4. Conclusion

The framework of present study shows that there are a few potential susceptible areas. This framework provides a good spatial prediction and overview on location of potential susceptible areas surrounding Murum Reservoir.

The findings from this study will serve as input parameters for the next stage of research and verified with Landslide Inventory Map. The next step is to couple this framework with a hydro-geotechnical tool, TRIGRS (Transient Rainfall Infiltration and Grid-based Regional Slope-Stability Analysis) to provide a temporal prediction in terms of the timing of landslide occurrence. Different case scenarios of storm events will be tested with soil parameters, topography parameters and hydrology parameters extracted from GIS analysis. The expected future outcomes from the coupled analysis will produce a factor of safety (FS) map and pore water pressure map over a storm period

Acknowledgement

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